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Evolution of olive oil production and its variations in the Bejaia province

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***Abstract*---**This study focuses on the evolution of olive oil production in the Bejaia province, highlighting the factors that influence this evolution. The main objective is to analyze the trends in olive oil production over time and identify the main determinants of these variations. Data on olive oil production over a period of twenty years have been collected and subjected to in-depth analysis. Statistical analysis was performed using the ARDL method to assess the factors that impact olive oil production. The results of the study highlight an upward trend in production. However, this growth is influenced by various factors. The study identifies several challenges to address for the olive sector in the Bejaia province, including the need to improve agricultural techniques, modernize equipment, and invest in research and development.

***Keywords*---**Olive Oil Production, Determining Factors, Production Trends, Agricultural Practices, Bejaia Province**.**

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Introduction

In recent years, olive oil producers have faced a complex dilemma. On one hand, international markets require increasingly stringent quality standards, demanding advanced technological expertise and the ability to anticipate changes in demand (Lernoud, 2017). On the other hand, the environmental impacts of this industry raise concerns about the sustainability of current practices, prompting a reevaluation of production methods to balance yield and ecosystem preservation (Maesano, 2021). In Algeria, and particularly in the Bejaia province, olive cultivation plays a central role in the agricultural economy of this region. This study focuses on the evolution of olive oil production in this coastal area of Algeria, highlighting the various factors that influence this dynamic. The main objective of this research is to analyze the trends in olive oil production over the past two decades, while identifying the main elements that explain these variations. This approach is based on a methodology that combines quantitative and qualitative analyses. Data on olive oil production, compiled over a twenty-year period, were rigorously collected and subjected to detailed analysis. In addition, in-depth interviews were conducted with local stakeholders, including farmers, cooperatives, and local authorities, to obtain contextual and qualitative insights. This comprehensive approach allows for an understanding of the complexity of the issues underlying olive oil production in the Bejaia province. The statistical analysis, conducted using the ARDL model, forms the backbone of the assessment of factors influencing olive oil production. In this approach, a range of economic and agricultural indicators were carefully considered. The results of this investigation reveal an upward trend in olive oil production in the Bejaia province in recent years. However, this growth remains subject to seasonal fluctuations and is influenced by various parameters, such as weather conditions, agricultural practices, and public policies.

This study identifies several challenges facing the olive oil sector in the Bejaia province. Among these, improving agricultural techniques, modernizing equipment, and substantial investments in research and development are necessary. Additionally, market diversification and the promotion of olive oil product quality represent promising avenues for stimulating sustainable growth in this vital sector. Given the evolving dynamics of olive oil production in the Bejaia province and the multiple factors influencing it, how can an integrated strategy be implemented, combining the modernization of agricultural techniques, investments in research and development, market diversification, and product quality improvement, to foster sustainable and long-term growth in this sector for the local economy? Modernizing agricultural techniques, combined with substantial investments in research and development, could lead to a significant and sustainable increase in olive oil production in the Bejaia province. Moreover, market diversification and improving the quality of olive oil products could play a key role in stimulating the growth of the olive oil production sector in Bejaia, opening new opportunities and attracting more consumers. However, olive oil production in Bejaia faces several constraints and challenges that threaten its sustainability and development. Among these constraints are the aging of olive groves, lack of maintenance, climatic hazards, forest fires, low productivity, international competition, and lack of institutional support.

1. Olive oil production

Olive oil production has evolved significantly over time, influenced by various factors such as market trends, technological advancements, and sustainability concerns (Di Giacomo, 2022). Recently, increasing competition has been observed in the olive oil market, with particular interest in Mediterranean countries. This has an impact on the entire supply chain, from production to marketing. The effects of olive cultivation on agriculture are an important element that has been the subject of extensive research. This cultivation influences soil quality and plays an essential role in environmental preservation (Bernardi, 2018). Therefore, it is imperative to adopt sustainable agricultural practices to ensure the sustainability of olive oil production. Climate change represents another major factor influencing olive oil production. The effects of climate on the entire supply chain, from olive tree growth to harvest, are increasingly noticeable. This reality requires adjustments in production methods and can also have repercussions on the quality of the final product. Similarly, technological advancements play a role in the olive oil industry. There is an increasing use of non-destructive methods to assess the quality of olives and the oil produced (Stella, 2015). These technologies offer more efficient and precise means of monitoring and improving olive oil production.

Regarding the sustainability of olive oil production, it is evident that this is a central topic in current debates. The benefits of organic farming compared to conventional farming are being studied, highlighting the trade-offs between environmental sustainability and economic viability (Raz, 2024). Finding a balance between these two aspects is essential to ensure the sustainability of the industry. Additionally, traceability within the olive oil supply chain is gaining importance. Consumers are increasingly attentive to the origin and quality of food products, emphasizing the need for accurate and transparent tracking (Guido, 2020). Traceability systems play a vital role in ensuring the quality and authenticity of olive oil. The evolution of olive oil production is influenced by a combination of factors such as market trends, environmental issues, technological advancements, and traceability requirements (Abenavoli, 2016). It is imperative to implement sustainable practices and adopt innovative technologies to address current challenges and ensure the sustainability of the olive oil industry.

1.1. Global trends in olive oil production

In recent decades, there has been significant growth in olive oil production, driven by increasing global demand fueled by the recognition of the health benefits of extra virgin olive oil. Spain, Italy, Greece, Tunisia, and Turkey stand out as the main producers, benefiting from a long- standing olive oil tradition and occupying a leading position on the global stage (Lernoud, 2017). Olive oil production is subject to various influences such as weather conditions, agricultural practices, and harvesting methods, which can lead to yield variations from year to year. To improve production and the quality of olive oil, the olive oil industry has incorporated modern technologies, such as the adoption of advanced irrigation systems, the use of mechanized harvesting techniques, and more efficient processing methods (Stella, 2015). Changes in consumption trends and consumer preferences directly influence the demand for olive oil. At the same time, international markets impose increasingly rigorous quality standards. Thus, the trade of olive oil is a central pillar of the industry, with countries such as Spain, Italy, and Greece standing out as major exporters on the global stage (Lernoud, 2017).

1.2. Innovative technologies in the olive oil sector

The olive oil industry has integrated various technologies to optimize production and enhance the quality of olive oil. This includes the adoption of modern irrigation systems, the use of mechanized harvesting techniques, and more efficient and environmentally friendly processing methods (Stella, 2015). Contemporary sensors and monitoring systems allow real-time tracking of agricultural parameters such as soil moisture, irrigation needs, and olive tree health. These data are important for precise and efficient plantation management (Stella, 2015). The adoption of modern harvesting machines automates the olive picking process, thereby increasing efficiency and reducing reliance on human labor. Olive oil extraction methods, such as two- or three-phase centrifuges, enable the production of higher quality oils more efficiently (Stella, 2015). Advanced techniques such as near-infrared spectroscopy (NIRS) and high-performance liquid chromatography (HPLC) are used to assess the quality of olive oil, particularly its fatty acid and phenolic compound composition. Geographic Information Systems (GIS) are used to map and monitor olive tree plantations, facilitating more efficient agricultural management planning (Rugini, 2016). The use of drones and satellite imagery is common for conducting aerial surveys and monitoring the health of olive groves, enabling informed decisions regarding agricultural interventions (Stella, 2015). These technological advancements contribute significantly to improving the productivity, quality, and sustainability of olive oil production, providing producers with essential tools to address the current challenges of the industry.

1.3. Climate change and its impact on olive oil production

Weather fluctuations, whether periods of drought or extreme temperatures, influence olive oil production. Olive trees are sensitive to these conditions, which can cause variations in yields from year to year (Bortoluzzi, 2023). These weather variations, encompassing temperatures, rainfall, and drought patterns, directly affect the growth and development of olive trees. Extreme weather conditions, such as prolonged heatwaves or drought periods, can lead to reduced yields by decreasing the quantity and size of olives produced (Lavermicocca, 2010). Moreover, these climate variations can alter the chemical composition of olive oil, particularly its fatty acid and phenolic compound content, thereby influencing its quality and organoleptic characteristics (Deiana, 2023). To address these changes, olive oil producers must implement adaptive strategies, such as adjusting agricultural management practices, selecting resistant olive tree varieties, and implementing efficient irrigation systems. Ongoing research in agro- meteorology and agro-ecology aims to propose innovative solutions to mitigate the impacts of climate change on olive oil production (Lavermicocca, 2010). These climate variations can have significant economic repercussions for the olive oil industry, affecting producers' incomes and competitiveness in the global market. It is important to note that these effects can vary depending on the region and its local specificities. Therefore, it is imperative to adopt approaches tailored to each context to mitigate the consequences of climate change on olive oil production.

1.4. Sustainability and agricultural practices

Sustainability has taken a central place in olive oil production, with many farms adopting environmentally friendly practices. Among these, organic farming, soil conservation, and effective water management have become important pillars. The shift towards organic farming practices is gaining ground in the olive oil industry. It is based on the application of biological methods for crop management, thereby promoting biodiversity and limiting the use of synthetic chemical products. The implementation of soil conservation techniques is necessary for preserving soil fertility and reducing erosion, encompassing the use of mulch, cover crops, and other sustainable management approaches (Rugini, 2016). Water management, through efficient irrigation, is essential to ensure optimal yields while minimizing water consumption. The adoption of modern irrigation systems, such as drip irrigation, contributes to more rational water use. Crop rotation with other plants can promote soil health by avoiding nutrient depletion and reducing pressure from olive tree-specific diseases (Rugini, 2016). Valorizing by-products of the olive oil industry, such as olive pomace and olive leaves, represents a way to contribute to sustainability by reducing waste and providing raw materials for other industrial sectors. Many olive oil farms seek to obtain recognized sustainability certifications, which testify to their commitment to environmentally friendly agricultural practices (Lernoud, 2017). These sustainable agricultural practices are indispensable for ensuring the long-term viability of the olive oil industry while preserving natural resources and the environment. They also help meet the growing consumer demand for responsibly produced food products.

1.5. Quality and traceability

Traceability of olive oil products has become fundamental to guarantee the authenticity and quality of olive oil. Consumers are increasingly attentive to the origin and production methods of food products, thereby stimulating the demand for reliable traceability systems (Guido et al., 2020). Establishing and adhering to rigorous quality standards is essential to ensure the reliability and safety of olive oil products. These standards encompass various aspects such as chemical purity, acidity, stability, and organoleptic characteristics of the oil (Bendini, 2007). Quality control procedures are implemented throughout the production chain, from olive cultivation to oil bottling. This includes chemical and sensory tests, as well as compliance assessments with established standards (Bendini, 2007). Many farms seek to obtain quality certifications and controlled origin labels that attest to the authenticity and quality of their products. These certifications serve as trust indicators for consumers (Guido, 2020). Traceability is essential to track the journey of a bottle of olive oil from its production site to the final consumer, thereby guaranteeing the authenticity and origin of the product (Guido, 2020). Modern technologies such as QR codes and RFID chips are used to provide consumers with detailed information on the origin and quality of olive oil (Lernoud, 2017). Traceability and quality certification play a role in combating counterfeiting and authenticating olive oil products on the market (Guido, 2020). These measures aim to ensure that consumers receive high-quality, authentic olive oil products that comply with established standards.

1.6. Economic impact of olive oil production

The olive oil industry plays an important economic role in many regions, generating jobs and contributing to local incomes. It is particularly important in Mediterranean countries, where it represents a substantial portion of agricultural revenues, also promoting employment and exports (Chikhi, 2014). Often rooted in rural communities, olive oil production is a vital element in maintaining agricultural activity and the local population. The olive oil market is subject to price fluctuations, influenced by factors such as global production, consumer demand, and climate variations. Agricultural policies and government subsidies have a significant impact on the olive oil industry, influencing production incentives, investments, and agricultural practices (Chikhi, 2014). The industry is also subject to international standards and regulations, established by organizations such as the WHO's Codex Alimentarius and the International Olive Council, thereby ensuring the quality, food safety, and traceability of products (Bendini, 2007). Environmental regulations, particularly those related to pesticide use and irrigation, impact agricultural practices and the sustainability of the olive oil industry. Additionally, marketing policies, such as customs duties and international trade agreements, influence the trade and export of olive oil between countries (Lernoud, 2017). These economic and political aspects exert a major influence on the dynamics of the olive oil industry, affecting production, product quality, and the economic conditions of sector stakeholders.

1.7. Challenges and opportunities in olive oil production

Despite its positive growth, the olive oil industry faces challenges such as increased competition in the global market, climate variations, and environmental pressures. However, these challenges also come with numerous opportunities for innovation and expansion into new markets. Climate change, with its impacts on olive oil production in terms of yields and quality, represents a major challenge for producers. Additionally, price fluctuations, global competition, and increasing consumer expectations regarding quality and traceability constitute challenges to be addressed by industry stakeholders. Strict regulations on food safety, quality, and traceability impose rigorous requirements on olive oil producers, which can represent a challenge in terms of compliance (Bendini, 2007). Although the adoption of sustainable agricultural practices is necessary, it may sometimes require significant initial investments and adjustments in production methods. Furthermore, the growing global demand for high-quality and authentic food products, such as extra virgin olive oil, opens up prospects for producers who emphasize the quality and traceability of their products (Lernoud, 2017). The adoption of innovative technologies, such as advanced agricultural monitoring and improved extraction techniques, offers opportunities to enhance productivity and olive oil quality (Stella, 2015).

Additionally, expansion into new markets, particularly emerging markets, represents a growth opportunity for olive oil producers. Finally, the creative valorization of olive oil industry by- products, such as the use of olive pomace for energy or cosmetics production, can provide an additional source of income for producers. By addressing these challenges with innovation and seizing the opportunities that arise, the olive oil industry can continue to thrive and adapt to the changing needs of the global market.

1.8. Future prospects for olive oil production

The future of olive oil production will likely be shaped by factors such as continued technological innovation, evolving consumer preferences, and environmental regulations. The industry will need to adjust to these changes to maintain its sustainability and competitiveness. The ongoing adoption of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and data analytics offers opportunities to improve the productivity, quality, and sustainability of olive oil production (Stella, 2015). The increasing pressure for sustainability and environmental responsibility is expected to encourage the adoption of more sustainable agricultural practices and the implementation of sustainability certifications. Olive oil producers are increasingly exploring product diversification, creating ranges of flavored oils, derived products, and olive oil-based skincare items (Lernoud, 2017). They will also need to persist in their efforts to adapt to the effects of climate change by developing resistant olive tree varieties and implementing adaptation practices (Lavermicocca, 2010). The opening of new markets in developing regions offers growth opportunities for the olive oil industry, provided that the needs and preferences of local consumers are understood and addressed. Educating consumers about the benefits of high-quality olive oil and the distinctions between different oil categories can influence purchasing preferences and demand (Bendini, 2007). These future prospects paint a dynamic landscape for the olive oil industry, with numerous opportunities for innovation, sustainability, and growth. However, it is essential to address the challenges associated with climate change, regulation, and market evolution.

2. Study model and standard analysis method

The Bejaia province stands as an undisputed pioneer in olive oil production at the national level, playing a central role in Algeria's agricultural economy. Each year, it contributes significantly, accounting for approximately a quarter of the country's total production (Zaidi, 2021). However, this contribution is not constant across seasons and years. It is primarily focused on olive oil production, with a relatively modest proportion of olives dedicated to other uses such as preservation. This situation reflects not only the economic importance of olive cultivation for the region but also highlights the need to adopt proactive measures to stabilize and diversify production. Indeed, the volatility of olive oil production can be influenced by a multitude of factors, including weather conditions, agricultural practices, and public policies. Therefore, implementing strategies to mitigate the effects of these variables and encourage more consistent production is of paramount importance for the long-term sustainability of this essential sector. Moreover, the relative predominance of olive oil production suggests opportunities for diversification. Exploring markets for other olive-derived products, as well as developing innovative preservation techniques, could open new perspectives and strengthen the sector's resilience to market fluctuations. By investing in research and development, and modernizing equipment and agricultural techniques, the Bejaia province can position its olive oil sector on a trajectory of sustainable growth adapted to future challenges.

2.1. Variables and study model

In this study, we will use the Autoregressive Distributed Lag (ARDL) regression method, and the data will be analyzed using the Eviews software. This analysis incorporates four independent variables: the area dedicated to olive cultivation (expressed in hectares), the average production per olive tree (measured in kilograms per tree), the average quantity of olive oil purchased (expressed in liters per quintal), and the average temperature. The dependent variable in this study is olive oil production (expressed in hectoliters). The period under consideration spans from 2000 to 2020. The chosen model is based on the following logarithmic formulation:

$$\mathbf{Log(Yt) = \alpha + \beta1\ log(X1t) + \beta2\ log(X2t) + \beta3\ log(X3t) + \beta4\ log(X4t) + \delta\ TREND + Ut} \quad (1)$$

Where: ***α*:** constant (intercept).
***β*i:** represents the estimation coefficients.
***δ* :** Time coefficient.
log→ Natural logarithm.
Yt: Olive oil production at time **t**.
X1t: The area cultivated with olives at time **t**.
X2t: Average annual olive production per tree at time **t**. **X3t:** Average olive oil extraction at time **t**.
X4t: Average temperature at time **t**. **TREND:** Time trend.
Ut : Random variable.

2.2. Standard study and unit root test results

The Augmented Dickey-Fuller (ADF) test was performed on the time series at its level and first difference, using a significance level of 5%. This was done using only the model with a constant, then adding a general trend. Additionally, a model without any of these specifications was also considered. The lag period (Lag Length) was chosen to ensure that the model with the random limit is free from autocorrelation, based on the Akaike Information Criterion (AIC). The results obtained after applying the tests on the study data using Eviews 9 are presented in this table.

Table 1: Results of the augmented dickey-fuller test for time sseries stationarity

integration case 1(d)	ADF stats						variables
	1st Difference			At Level			
	Without Constant & Trend	With Constant & Trend	With Constant	Without Constant & Trend	With Constant & Trend	With Constant	
1(0)	0.1069	0.0006***	0.0003***	0.9806	0.0006***	0.9941	**Yt**
1(1)	0.0063***	0.0364**	0.0132**	0.9958	0.9287	0.9918	**X1**
1(0)	0.0000***	0.0004***	0.0001***	0.9723	0.0003***	0.9906	**X2**
1(0)	0.0000***	0.0066***	0.0011***	0.7489	0.0053***	0.0053***	**X3**
1(0)	0.0000***	0.0003***	0.0000***	0.7402	0.0691*	0.0024***	**X4**

Source: Prepared by the authors based on Eviews 9 results
***, **, * are statistically significant at 1%, 5%, and 10%, respectively

The results of the unit root tests, as indicated in Table (1) above, demonstrated that the time series for each of the elements (olive oil production, average annual olive production, average olive oil extraction, average temperature) is stable at its level. However, the time series for the variable of the area cultivated with olives was not stable at its level. Therefore, the null hypothesis was retained, suggesting that the series has unit roots (non-stationary at the level). This necessitated taking the first difference to stabilize these variables, without the presence of a general or categorical trend below a significance level of 1%.

2.3. Results of the unrestricted error correction model (UECM) tests

The autoregressive distributed lag model is highly dependent on lag periods, and when running the test, the Eviews software automatically determines the lag period based on the specified criterion, in this case, the AIC (Akaike Information Criterion). The results show that for olive oil production, Eviews 9 suggested a lag period of (ARDL) 1,0,0,0,0), while the other variables (area planted with olives, average annual olive production, average olive oil extraction, average temperature) did not require any lag.

Table 2: Results of the unrestricted error correction model (UECM) tests

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOG(Y(-1))	0.007210	0.005317	1.356019	0.1982
LOG(X1)	0.321450	0.096345	3.336443	0.0054
LOG(X2)	1.004093	0.005749	174.6680	0.0000
LOG(X3)	0.977099	0.028696	34.05052	0.0000
LOG(X4)	0.073070	0.012449	5.869548	0.0031
C	2.282970	1.011833	2.256272	0.0419
@TREND	0.002155	0.001009	2.135163	0.0524
R-squared	0.990817	**Mean dependent var**	11.66925	
Adjusted R-squared	0.990733	**Durbin-Watson stat**	1.593262	

Source: Prepared by the authors based on Eviews 9 results

The results of the statistical tests for the regression equation, presented in Table (2) above, clearly demonstrate that the model's coefficient of determination reaches (R2 = 99%). This indicates that the independent variables explain 99% of the variation in olive oil production. Although the variables included in the model (area cultivated with olives, average annual olive production, average olive oil extraction, average temperature) are significant, the high coefficient of determination can be considered a challenge for the regression. Indeed, it may reduce the relevance of other variables that were not considered, either due to a lack of data or because they were excluded in the absence of complete data series.

2.4. Results of the ARDL bounds test for cointegration

The ARDL bounds test is a method used to assess the existence of long-term relationships between the model's variables. It examines the cointegration between these variables to determine whether they maintain a stable and lasting relationship over the long term. Here are the test results:

Table 3: Results of the ARDL bounds test for cointegration

Test Statistic	**Value**	**k**
F-statistic	9.140020	4
Critical Value Bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	3.03	4.06
5%	3.47	4.57
2.5%	3.89	5.07
1%	4.4	5.72

Source: Prepared by the authors based on Eviews 9 results

The results in Table (3) clearly indicate that the F-statistic value is 9.140020, surpassing all critical values in the table. This leads to the rejection of the null hypothesis, which suggests the absence of cointegration, in favor of the alternative hypothesis that confirms the existence of cointegration between the model's variables. This finding confirms the existence of a long-term equilibrium relationship between olive oil production and the independent variables examined. This implies that these variables maintain stable and lasting long-term relationships, which is an essential prerequisite for conducting more in-depth analyses using the ARDL model. This conclusion has significant implications that can greatly influence the decision-making process and policy formulation. Here are some of the implications of this finding: Cointegration highlights the existence of stable and lasting relationships between the variables, meaning that changes in the independent variables have long-term repercussions on olive oil production, beyond short-term variations. This provides insight into how these variables interact and influence each other over extended periods. In terms of policy formulation, decision-makers can use the cointegration results to develop policies that will be both effective and sustainable for the olive oil sector. Policy interventions targeting the independent variables are likely to have persistent effects on olive oil production, thereby enabling more informed decisions and strategies. As for business strategies and investments, producers, farmers, and investors can leverage the information from cointegration to make informed decisions. For example, farmers can plan planting strategies based on stable relationships between the planted area, tree yield, oil extraction, and temperature. The implementation of cointegration allows for more efficient resource allocation. For instance, investments can be directed towards improving olive yield per tree or optimizing extraction methods, knowing that these efforts will have lasting effects on production. Finally, cointegration advocates for long-term investments. Investors can confidently allocate their resources to projects aimed at boosting olive oil production, knowing that the effects will endure over time.

3. Results of ARDL cointegration and long-term estimation:

To determine the long-term effect, we estimated the long-term coefficients of the model. Here are the results obtained:

Table 4: Results of the long-term model estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(X1)	0.323785	0.096926	3.340546	0.0053
LOG(X2)	1.011385	0.009762	103.604041	0.0000
LOG(X3)	0.984195	0.030427	32.346469	0.0000
LOG(X4)	0.073070	0.012449	5.869548	0.0031
C	2.299549	1.019127	2.256390	0.0419
@TREND	0.002171	0.001012	2.144889	0.0514

Source: Prepared by the authors based on Eviews 9 results

Based on the data in Table (4), the long-term model equation can be expressed as follows:

$$\mathbf{Cointeq} = \mathbf{LOG(Y)} - (\mathbf{0.3238} * \mathbf{LOG(X1)} + \mathbf{1.0114} * \mathbf{LOG(X2)} + \mathbf{0.9842} * \mathbf{LOG(X3(} \\ \mathbf{0.0736} * \mathbf{LOG(X4)} + \mathbf{2.2995} + \mathbf{0.0022} * \mathbf{@TREND} \ (\rightarrow (2)$$

It is clear from Table (4) that the long-term equation for the model's variables reveals that all explanatory variables have a positive relationship with olive oil production, confirming the study's hypothesis. It was found that the average annual olive production per tree was significant at a confidence level of 1%, with a positive effect. Indeed, a 1% increase in the average annual olive production per tree leads to a 1.01% increase in olive oil production. This direct and proportional correlation is of importance in planning and production. Indeed, this has several major implications for the olive oil industry and associated sectors:

Strategies to increase yield: The significance of this variable highlights that initiatives aimed at increasing the annual production of olive trees can generate substantial benefits. Investments in improving agricultural practices, pest control, irrigation, and soil management can directly boost olive tree productivity, thereby stimulating olive oil production.

Variety selection: This result encourages farmers to choose olive tree varieties known for their high productivity. By favoring the planting of olive tree varieties that produce more fruit, farmers can naturally contribute to increasing olive oil production.

Resource allocation: Given the predominant influence of this variable, it can guide decisions regarding resource allocation. Farmers and producers can prioritize investments and interventions aimed at increasing olive tree production to maximize total olive oil production.

Decision-making support: The result provides decision-makers with quantifiable data. Policymakers can assess the impact of specific interventions or incentives aimed at improving olive tree productivity, thereby estimating their influence on total olive oil production.

Research and development: The result underscores the importance of ongoing research and innovation in agricultural technologies. Advances in tree genetics, crop management, and agricultural techniques can lead to significant increases in productivity. Furthermore, the average olive oil extraction was found to be significant at a 1% level, with a positive coefficient of 0.98. This means that a 1% increase in the average olive oil extraction leads to a 0.98% increase in olive oil production. This finding highlights the importance of efficient oil extraction methods for increasing olive oil production over time. This conclusion has major implications for the olive oil industry, influencing processing practices and overall production strategies.

Optimal extraction techniques: The significance of average olive oil extraction underscores the importance of efficient extraction methods for the industry. Investing in advanced and high- performance extraction technologies can have a direct impact on overall olive oil production.

Quality improvement: Efficient extraction methods not only increase production but also help maintain the quality of olive oil. Proper extraction processes are essential to preserve the desired properties, flavors, and nutritional value of the oil.

Yield maximization: Efficient extraction methods complement efforts to increase olive tree productivity. By combining increased tree productivity with efficient oil extraction, it is possible to achieve a significant increase in overall olive oil production.

Resource optimization: Improving extraction methods can enhance resource utilization. By obtaining more oil from the same quantity of olives, farmers can increase the efficiency of invested resources.

Innovation and research: The importance of extraction methods highlights the need to continue investing in research and innovation in olive oil extraction techniques. These advancements can increase extraction efficiency and improve yields. It was also found that the area cultivated with olives is significantly below the 1% significance level, with a positive effect, as its coefficient reaches (0.32), meaning that a 1% increase in the area cultivated with olives leads to a 0.32% increase in olive oil production. This indicates that increasing the area dedicated to olive cultivation can lead to sustainable growth in olive oil production in the long term. This result has several implications for the olive oil industry, agricultural planning, and overall production strategies:

Expansion and growth: The significance of the cultivated area variable indicates that increasing the area planted with olives directly contributes to increased olive oil production. Expanding the areas dedicated to olive cultivation can lead to increased production.

Resource allocation: Farmers and producers can strategically allocate resources to develop olive cultivation, knowing that this will lead to increased olive oil production. This can include land tenure, improved irrigation, and effective land use planning. Moreover, it was found that the average temperature is significant below the 1% significance level and has a positive effect, as its coefficient is (0.07), meaning that a 1% increase in average temperature leads to a 0.07% increase in olive oil production. This suggests that regions with warmer climates could have greater potential for olive oil production in the long term. This result has several implications:

Adaptation to climate change: This result confirms the importance of understanding the impact of climate change on olive oil production. High temperatures can affect growth cycles, production, and oil quality. Adapting to temperature changes becomes essential.

Variety selection: Farmers can choose olive tree varieties that are more tolerant or adapted to current temperature conditions. Selecting cultivars suited to the local climate can lead to better yield outcomes.

4. Results of the Restricted Error Correction Model (ECM) Tests

In this approach, the vector error correction model takes into account the short-term relationship as well as temporary fluctuations. It is developed based on the direction of the long-term relationship. During this process, the short-term relationship is estimated by introducing the estimated residual variable (ECM) into the long-term regression, considering it as a lagged independent variable over a period. This methodology ensures a dynamic connection between the short-term and long-term relationship of the model's variables throughout the adjustment process, aiming to achieve long-term equilibrium, as shown in the following equation:

$$\Delta \mathrm{Log}(Y_t) = \delta\ \Delta \mathrm{TREND} + \beta_1\ \Delta \log(X_{1t}) + \beta_2\ \Delta \log(X_{2t}) + \beta_3\ \Delta \log(X_{3t}) + \beta_4\ \Delta \log(X_{4t}) + \beta 4 \mathrm{ECM}_{t-1}$$

The results are presented in the following Table (5):

Table 5: Results of the restricted error correction model (ECM) tests for long-term coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(X1)	0.321450	0.096345	3.336443	0.0054
DLOG(X2)	1.004093	0.005749	174.667960	0.0000
DLOG(X3)	0.977099	0.028696	34.050523	0.0000
DLOG(X4)	0.073070	0.012449	5.869548	0.0031
D(@TREND())	0.002155	0.001009	2.135163	0.0524
CointEq(-1)	-0.992790	0.005317	-186.725108	0.0000

Source: Prepared by the authors based on Eviews 9 results

Table (5) highlights the following points: The error correction parameter satisfies both criteria: it is significant at the 1% level and negative. The value of CointEq(-1) = (-0.99) reinforces the accuracy and validity of the long-term equilibrium relationship. This means that the model is capable of correcting the error and returning to normal within an estimated period of about one year. In other words, when there is a deviation in olive oil production from its long-term equilibrium value in the previous period (t-1), it is possible to correct 99% of this imbalance in period t, to return to long-term equilibrium.

The average annual tree production is significant at the 1% level and has a direct effect, with a coefficient of (1.004). This indicates that a 1% increase in the average annual tree production leads to a 1.004% increase in national olive oil production in the short term. This underscores the importance of improving the yield of individual olive trees for an immediate increase in olive oil production. The short-term elasticity of average olive oil extraction is 0.98, meaning that a 1% increase in average olive oil extraction leads to a 0.98% increase in olive oil production in the short term. This highlights the importance of improving extraction techniques to increase production. The short-term elasticity of the area cultivated with olives is 0.32, indicating that a 1% increase in the area cultivated with olives leads to a 0.32% increase in olive oil production in the short term. This suggests that expanding cultivated areas can lead to an immediate increase in olive oil production. The short-term elasticity of temperature is 0.072, meaning that a 1% increase in temperature leads to a 0.072% increase in olive oil production in the short term. This indicates that warmer temperatures can favor an increase in olive oil production in the short term by creating more favorable growth conditions.

5. Diagnostic test results of the study model

5.1. Results of the model's structural stability test

The structural stability of the estimated coefficients of the autoregressive model with distributed lags is established when the CUSUM and CUSUM of Squares test graphs fall within the critical limits at the 5% significance level. Conversely, if the graphs exceed the critical limits, it indicates instability in the equation. The two figures below present the results of the two tests:

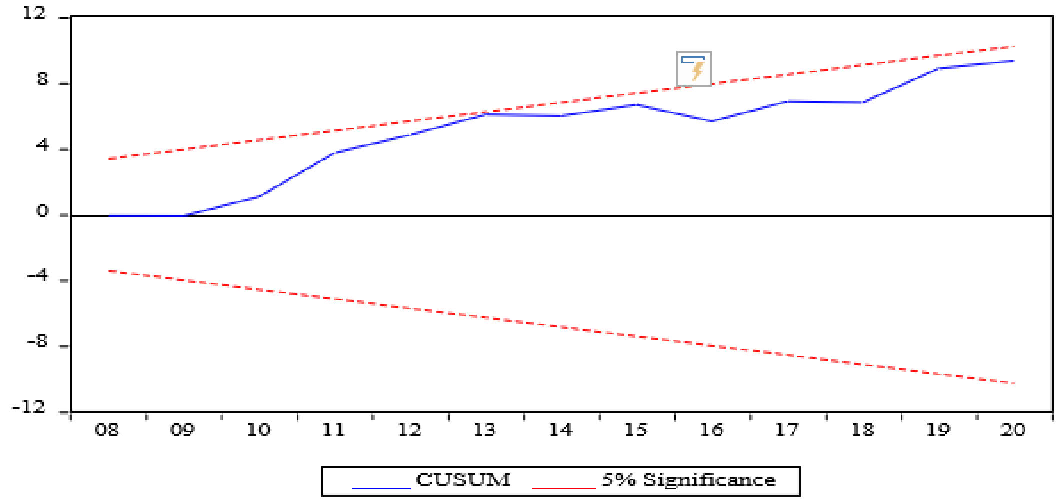


Figure 1: Results of the cumulative sum of residuals tests
Source: Prepared by the authors based on Eviews 9 results

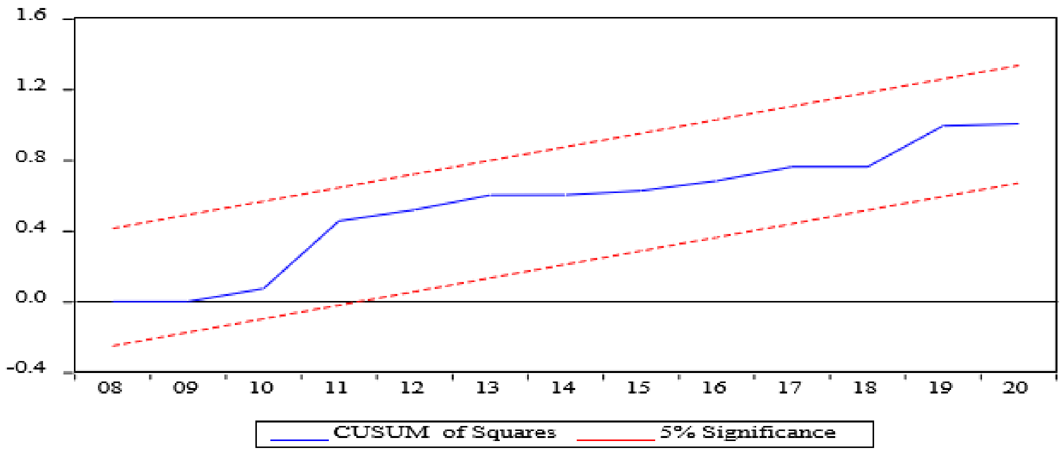


Figure 2: Results of the cumulative sum of squared residuals tests
Source: Prepared by the authors based on Eviews 9 results

Figures 2 and 3 clearly demonstrate that the trajectory of the CUSUM and CUSUM of Squares test graphs remains within the critical limits at a 5% significance level. This confirms the structural stability of the model's estimated coefficients.

5.2. Results of the model's serial correlation tests

To ensure that the model is free from serial correlation issues, the Breusch-Godfrey serial correlation LM test was used. According to Table (6) below, it appears that the probability values for each of the F-statistics and Chi-Square statistics are greater than 5%, indicating that the model does not exhibit any serial correlation problems.

Table 6: Results of the serial correlation LM test

F-statistic	0.423379	**Prob. F(2,11)**	0.6651
Obs*R-squared	1.429519	**Prob. Chi-Square(2)**	0.4893

Source: Prepared by the authors based on Eviews 9 results

5.3. Heteroskedasticity test

Table (7) below indicates that the probability values associated with each of the F-statistics and Chi-Square test statistics are greater than 5%. This confirms the homogeneity and stability of the model's variance, which is essential to ensure its reliability and consistency.

Table 7: Results of the ARCH heteroskedasticity test

F-statistic	**0.399429**	**Prob. F(1,17)**	**0.5358**
Obs*R-squared	**0.436172**	**Prob. Chi-Square(1)**	**0.5090**

Source: Prepared by the authors based on Eviews 9 results

5.4. Nonlinearity or polylinéarity test

To ensure that the model is free from multicollinearity issues between the independent variables, the Kline test was used. By comparing the coefficient of determination R2 with the square of the simple correlation coefficient between two independent variables, it is possible to determine whether there is a strong linear correlation between the independent variables, which may indicate a multicollinearity problem. If the R2 is higher than the square of the simple correlation, it suggests that there is no significant multicollinearity problem between the independent variables. This is a judicious approach to ensure the model's reliability.

Table 8: Matrix of simple linear correlation coefficients between the independent variables of the industrial sector financing model

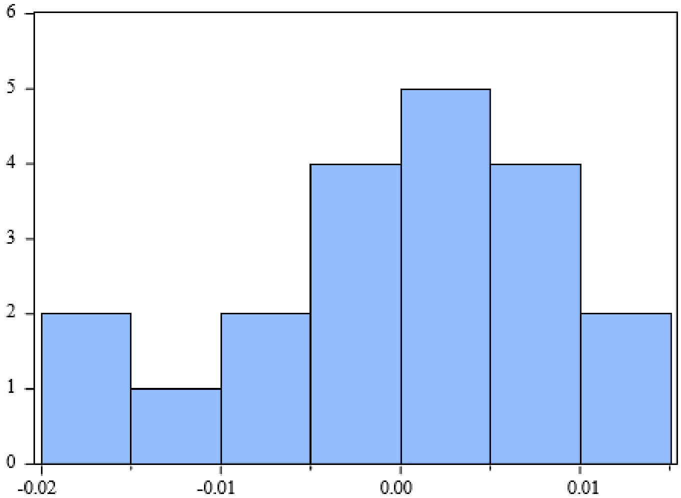
	X1	**X2**	**X3**	**X4**
X1	**1**	0.41	0.34	0.37
X3	0.41	**1**	-0.05	-0.04
X4	0.34	-0.05	**1**	0.24
X5	0.37	-0.04	0.24	**1**

Source: Prepared by the authors based on Eviews 9 results

It is clear from Table (8) that the model does not exhibit a linear participation problem between the independent variables. The square of the highest value of the simple correlation coefficients between two independent variables is 0.14, which is lower than the coefficient of determination R2 of 0.99. This indicates that the model's independent variables are not strongly correlated with each other, reinforcing the model's reliability.

5.5. Test of the Normal Distribution of Random Errors:

To ensure the normal distribution of the data, we used the Jarque-Bera test. Figure (3) below shows that the probability value associated with this test exceeds 5%. This indicates that the model's residuals follow a normal distribution, thereby reinforcing the model's validity and reliability.



Series: Residuals Sample 2001 2020
Observations 20

Mean	5.21e-16
Median	0.000862
Maximum	0.013658
Minimum	-0.015584
Std. Dev.	0.008440
Skewness	-0.399304
Kurtosis	2.407274
Jarque-Bera	0.824250
Probability	0.662241

Figure 3: Results of the Jarque-Bera Test
Source: Prepared by the authors based on Eviews 9 results

The analysis results demonstrate a significant relationship between the studied variables and olive oil production in the Bejaia province. The area cultivated with olives has a significant positive influence on olive oil production, indicating that expanding olive tree cultivation areas contributes substantially to increasing olive oil production in the region. Similarly, an increase in the average annual olive production per tree has a significant positive effect on olive oil

production, highlighting the importance of implementing effective agricultural practices to increase olive tree yields. The efficiency of the olive oil extraction process also has a positive impact on overall olive oil production, underscoring the importance of investing in modern and efficient extraction equipment and methods. Additionally, the average temperature shows a significant positive correlation with olive oil production, suggesting that regions with higher average temperatures are more conducive to increased olive oil production.

This study provides important information for decision-making and policy formulation aimed at increasing olive oil production in the Bejaia province. Based on the results, it is recommended to implement training and support programs for farmers, as well as economic incentives to encourage the adoption of modern agricultural practices. Furthermore, measures to strengthen cooperation among olive oil sector stakeholders and promote local products in national and international markets are essential to ensure a prosperous future for this sector.

Conclusion

The analysis of the determinants of olive oil production in the Bejaia province highlights strategic elements for the sector. Several factors interact to influence production, offering strategic opportunities and essential considerations. Controlled and sustainable expansion of the area cultivated with olives emerges as a major driver of increased production. However, it is imperative to consider environmental and sustainability aspects during this expansion. Simultaneously, optimizing olive tree productivity proves essential. The adoption of modern agricultural practices, as well as specific management and care techniques, are necessary to increase individual tree yields. These measures require training and support programs for farmers, as well as economic incentives to encourage their implementation.

The efficiency of the olive oil extraction process also presents itself as a necessary element. Investing in modern and efficient extraction equipment and methods is imperative to maximize yield, which translates into a direct and positive impact on total olive oil production. Additionally, the average temperature proves to be an influential factor. Regions with higher temperatures have greater production potential. However, it is essential to closely monitor the effects of climate change and adapt agricultural practices accordingly.

Finally, extensive tests were applied to ensure the model's structural stability and eliminate potential issues of autocorrelation and heteroskedasticity. The model demonstrated its robustness and reliability, providing a solid foundation for informed decisions and sectoral policies. Overall, this study provides information to guide decision-making and policy formulation aimed at stimulating olive oil production in the Bejaia province. Implementing training programs, strengthening cooperation among sector stakeholders, and promoting local products in national and international markets are essential to ensure a flourishing future for this key sector of the regional economy.

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